Simulating the Clinical Care of Patients: A Comprehensive Mathematical Model of Human Pathophysiology

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A comprehensive mathematical model of human pathophysiology has been combined with a clinically realistic computer interface in order to allow users to develop and refine clinical skills. Users apply medical diagnostic and treatment maneuvers that impact patient clinical and cost outcomes. The computer system will critique performance on several levels and allow users to replay the simulation to improve clinical insight.

INTRODUCTION

Fierce market pressures and dwindling patient volumes have compelled academic institutions--training centers--to join and compete in the managed care environment. As a result, housestaff training programs are evolving to meet these demands. Specifically, to the extent that physicians-in-training do not provide highly efficient and cost effective patient care, nontraditional means to gain clinical experience and measure effectiveness must be created. Computer applications combining a model of human disease coupled with a realistic graphical user interface allow users to gain clinical experience without adversely affecting the efficiency or cost of care.

DESCRIPTION

Model: The model is continuously iterative with discrete states and it consists of about 2300 simple and complex algebraic equations. The submodels of cardiovascular hemodynamics, renal fluid and electrolyte metabolism, energy and respiratory drive are derived from the work of A.C. Guyton. Using this as a nidus, we have integrated submodels (acid-base metabolism, pulmonary dynamics, and oxygen and drug metabolism) to achieve clinically necessary outputs and allow for meaningful clinical management input. The model's behavior can be varied by setting more than 50 intrinsic "patient" properties, e.g., cardiac muscle contractility, nephron mass, pulmonary airway inspiratory or expiratory resistance.

The model was validated using expert opinion.

Interface: The computer-interface has been developed with special emphasis on clinical realism. To that end, users interact with images of standard ventilator fronts (to set ventilation parameters or read airway pressures) when patient mechanical ventilation is initiated by the user. In addition, typical patient monitors are used to graphically portray patient data such as the electrocardiogram, arterial blood pressure waveform, Swan-Ganz readings and respiratory activity. Laboratory values and radiographs are also available. Patient vital signs and "I/O" information is presented, e.g., urine output, fluid intake. A group of standard medicines and fluids are available to use in treating patients. As in the clinical environment, the user must devise and then "order" the diagnostic and treatment plan.

Patient simulations are created as an ordered series of discrete patient states. (The simulations are created in a custom MS ACCESS-based authoring program.) Each discrete state contains patient history and physical examination information, images, as well as numerical model inputs (intrinsic patient properties). The computer program changes states gradually over a time period specified by the author.

Reports: At the end of each simulation (determined by "patient" death, recovery, a simulation time limit, or the user) the cost of the user's diagnostic and treatment maneuvers is provided. This can be compared with a cost summary of the optimal diagnostic and therapeutic steps.

The simulation's initial states and important clinical data are displayed along with the users' key interventions.

After reviewing performance summaries, the user may replay the whole simulation or "rewind" to a specific point to try a new management approach. By repeating the simulations, the user can acquire and refine appropriate management skills.

System Requirements: This application requires a IBM-compatible PC running DOS and MS Windows version 3.0 or later. The microprocessor should be an i486-66 or faster. The monitor must be capable of displaying a resolution of 1024x768. A mouse or similar input device should be used.

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